Knowledge maps in agriculture and rural development

Znalostní mapy v zemědělství a rozvoji venkova

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Abstract: The possibility of knowledge maps use in the decision-making process in agriculture and rural development is discussed in this paper. Each knowledge map presents a visualization of knowledge using different tools, where a mathematical model can be applied as one of them. The hierarchical structure of a knowledge map conforms to the general structure of a mathematical model. The mathematical model, when successfully solved and correctly read, is a knowledge map in itself. The parallels exist also between the creation process of a mathematical model and of a knowledge map. In general, every phase of a system approach can lead to a special knowledge map. The following paper explains this process and demonstrates it on the farm production structure optimisation problem solved by using a linear programming model.

Key words: knowledge formalisation, system approach, decision-making, map creation process, model creation process

Abstrakt: Znalostní mapy mohou být významným nástrojem při řešení problémů zemědělství a venkova. Každá znalostní mapa vizualizuje znalost pomocí různých nástrojů. Speciálním typem této vizualizace či formalizace může být matematický model, protože hierarchická struktura znalostní mapy odpovídá obecné struktuře matematického modelu. Správně aplikovaný úspěšně řešený matematický model je tedy znalostní mapou. Existuje také paralela mezi postupem tvorby znalostní mapy a matematického modelu. Proces aplikace znalostních map ve formě matematických modelů je ukázán na řešení problému optimalizace zemědělské výrobní struktury. Každá fáze systémového přístupu vede k tvorbě a aplikaci speciální znalostní mapy.

Klíčová slova: formalizace znalostí, systémový přístup, rozhodování, tvorba map, tvorba modelů

Rapid changes in the external environment require the decision-makers to select new approaches and methods of decision-making (Svoboda 2008). Information and knowledge systems based on knowledge approach and OR/MS methods have an important role in this process. Quality decision support systems and information and communication technologies and the quality of the provided information and knowledge for the decision-makers are an important source of competitiveness (Šilerová, Kučírková 2008). This quality is based on the user's satisfaction with these systems (Beránková et al. 2008) and their elements as mathematical models. In connection with these facts and with wide-spread theory of knowledge mapping, more and more questions dealing with their practical use arise.

Do we need to formalize knowledge? Do we need to formalize its using a knowledge map? What are we to do with a (mathematical) model to consider it as a knowledge map? Is the approach of the linear programming model construction (creation) process an analogue to the process of the knowledge map creation? Is there any relevant application of this process in agriculture and rural development? Some answers to these questions will issue from the following text. And finally: Can we read a solution from a model in the same way as knowledge from a map?

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MATERIAL AND METHODS

Knowledge and knowledge maps

Knowledge is a central term of knowledge management. Knowledge can be defined as a form of problem solution with its context, experience, interpretation, and reflection. It is a high-value form of information that is ready to be applied to decisions and actions (Davenport, Prusak 1998). The knowledge is generally defined as a dynamic human process of justifying personal beliefs as a part of the aspiration for truth.

Mapping knowledge in its authentic substance has a template in geographical mapping, particularly in military mapping. The first cartographers, who were already conscious of their limited knowledge, decorated their maps with various pictures of animals or dragons in those places where the exact data were missing. The maps documenting the ratio of knowledge in the face of ignorance arose in this way because knowledge in itself rises only on the basis of a successfully solved problem. Geographical maps were static in the principal points, but military maps included some dynamic features because of the drawings or other graphic descriptions of the battle or the progress of its stages (pre-battle tactics, battle strategy, and the possible post-battle situations – many times in various scenarios).

There are various definitions of the terms 'knowledge map' and 'knowledge mapping'. Stanford (2000, 2001) defines it as follows: "Knowledge mapping quite simply is any visualization of knowledge beyond the textual one for the purpose of eliciting, codifying, sharing, using and expanding knowledge". Graphic symbols play a key role in each knowledge map; their positions and spatial relationships are mostly expressed with the use of arcs or edges. The knowledge map must show a progression of ideas with relationships, beyond their being just spatial. Knowledge maps include conceptual relationships such as the chronological, hierarchical, associative, causal, logical and evaluative ones (Stanford 2001). The solving process should contain at least four steps of the Simon's problem decomposition, i.e. intelligence activity, design activity, choice activity, and review activity (Simon 1960). Gordon (2002) also shows that knowledge maps may be referred to as the maps of the way of acquiring knowledge. The knowledge maps are important as building knowledge tools as well as thinking tools (Rogers 2000).

Baron (2004) states that each knowledge map simplifies the visualisation of the reality and suggests that it should be divided according to the character of the evaluation or solution of the (successfully) solved problem. A knowledge map is a special type of a reality model, for instance a reality image.

We suggested the following classification of knowledge maps (Šubrt, Brožová 2007):
- Descriptive maps
  - Weak descriptive maps
  - Strong descriptive maps
- Normative maps
- Prescriptive maps

Descriptive maps (weak and strong) describe and simulate the real situation as precisely as possible. **Weak descriptive maps** describe the real situations using different kinds of symbols and arcs connecting them. Graph theory models are typical tools for building this kind of maps. Passing through this map helps the user to understand the problem and to increase his/her level of knowledge of "how" to solve a problem. The mutual positions of objects (elements) are unimportant, only the symbols themselves and the quality of their relationships are relevant for the map reading and problem solving. Not only objects, symbols or texts are important for s**trong descriptive knowledge** maps. To be a knowledge map of this type, the item must use spatial relationships to elicit, share and codify knowledge (Stanford 2001). Such a knowledge map must show a progression of ideas with relationships beyond their being just spatial. Geographical maps are typical representatives of strong descriptive maps.

Normative maps are related to a typical standard or norm, to optimal solution, or to the best decision. In this case, the aim of the knowledge map is to introduce the approach of how to reach the target (solution), or how to reach the comparative norm. Strategy maps cover the major part of this knowledge map type. Strategy maps are a way of providing a macro view of an organization strategy, and provide it with a language in which they can describe their strategy, prior to constructing the metrics to evaluate the performance against their strategy (Stanford 2001).

Prescriptive maps (Baron 2004) follow the normative and descriptive maps. They help to find ways to the solution selected according to the normative map. The prescriptive maps are mainly oriented on the process, not on the state or decision, so they have to consist not only of elements and branches but also of milestones.

Modelling process and knowledge maps

Operations Research/Management Science (OR/MS) modelling process (Stevenson 1989, Turban and Me-

Table 1. System approach and knowledge maps

Goal	System approach	Knowledge map
Understanding the problem	Problem definition	Mind map *Descriptive map*
Quantification concepts and their relations	System definition	Concept map *Descriptive map*
The best solution searching, model experiments, model solution	Mathematical model	Descriptive or normative map
Realisation of chosen solution	Problem implementation	Prescriptive map

Source: authors

redith 1991, Bonini at al. 1997) is a crucial part of the system approach to problem solving, regardless of the nature of the system, product, or service. The system approach and OR/MS modelling process represent the scientific solution of complex organisational decision problems. The improvement of an existing system and good designs for new systems are the goals of this approach.

The system approach can be represented as a path from the verbal problem definition, through the problem formalisation, the mathematical model and its solving, and the solution interpretation and implementation. This process needs some form of formalisation, especially various forms of symbolic knowledge maps (Table 1).

The knowledge maps creation process means to produce a hierarchical structure which consists of topics, ideas or concepts linked by branches to other elements. This scheme can use a word description of the map elements, a symbolic description and colours (Buzan 2005; Novak and Govin 1984; Brinkmann 2005). As Šubrt, Brožová (2007) mention, practically all types of successfully solved mathematical models, when correctly read, are knowledge maps of different types – descriptive, normative, prescriptive. The hierarchical structure of knowledge maps conforms to the general structure of mathematical models. The basic steps of the model creation process are thus equivalent to the steps of the knowledge map creation. The analogy between these steps is shown in Table 2.

Table 2. Analogy between model construction and creation of a KM

OR/MS model creation steps	Knowledge map creation steps
Variables	Topics, ideas or concepts
Constraints	Branches
Transformation	Branches
Evaluation	Evaluation

Source: authors

RESULTS AND DISCUSSION

Knowledge map as a result of the management science modelling process in agriculture

The basic steps of the agricultural technology weak descriptive knowledge map building will be discussed on the real example.

Problem formulation is the most important part of the decision-making process. The formulation of a problem is often more essential than its solution.

Table 3. Relationship between production and yield from particular products

Winter wheat	Spring barley	Sugar beet	Rape	Peas
1 : 2	1 : 5	1 : 4	1 : 8	1 : 5

Source: authors

Table 4. Yield and cost normative

	Winter wheat	Spring barley	Sugar beet	Rape	Peas
Labor costs (1 000 CZK per ha)	1.2	1.13	5.8	1.2	1.1
Mechanization costs (1 000 CZK per ha)	8.1	7.9	25	8.7	8.6
Revenue (1 000 CZK per ha)	50	12	36	12.4	13

Source: authors

In fact, understanding a problem usually indicates the ways and means of solving it.

Example: A farmer has available 200 ha of his/her own land and further 200 ha on lease. The rent amounts to 2 500 CZK per hectare per year. He/she has to decide about growing winter wheat, spring barley, sugar beet, rape or peas. For the sowing progress reasons, it is necessary to keep the definite ratio between the production and yield of the particular products. The necessary data are available in Table 3 and Table 4.

System definition means the first step of the problem formalisation. It is a representation of the modeller's thoughts about the reality and it is typically expressed by words and graphical symbols using the system theory terms as system, elements, relations, transformation, boundaries and so on. The definition of system boundaries, its subsystems, its components and their relations is an arbitrary process. General symbols can be used for the graphical description of defined system (Figure 1).

Example: Using the suggested symbols; the graphical representation of the system definition is in Figure 2. The dashed arrow in this chart indicates the ratio between production and yield of the particular products.

Model building is the base of the OR/MS modelling approach. The model is a representation of the

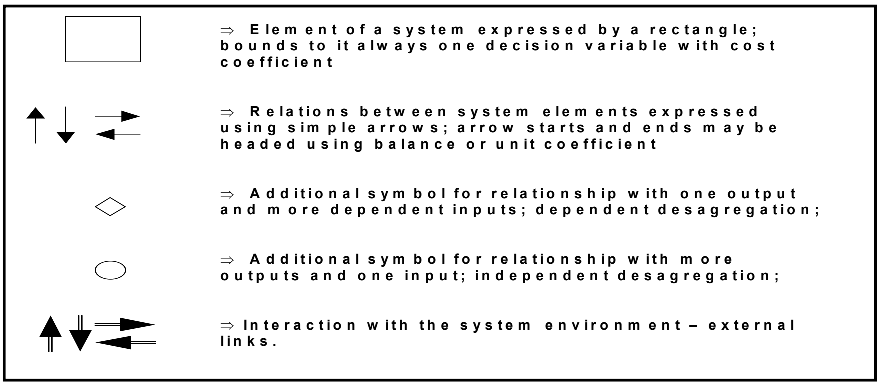

Figure 1. General symbols and their description

Source: authors

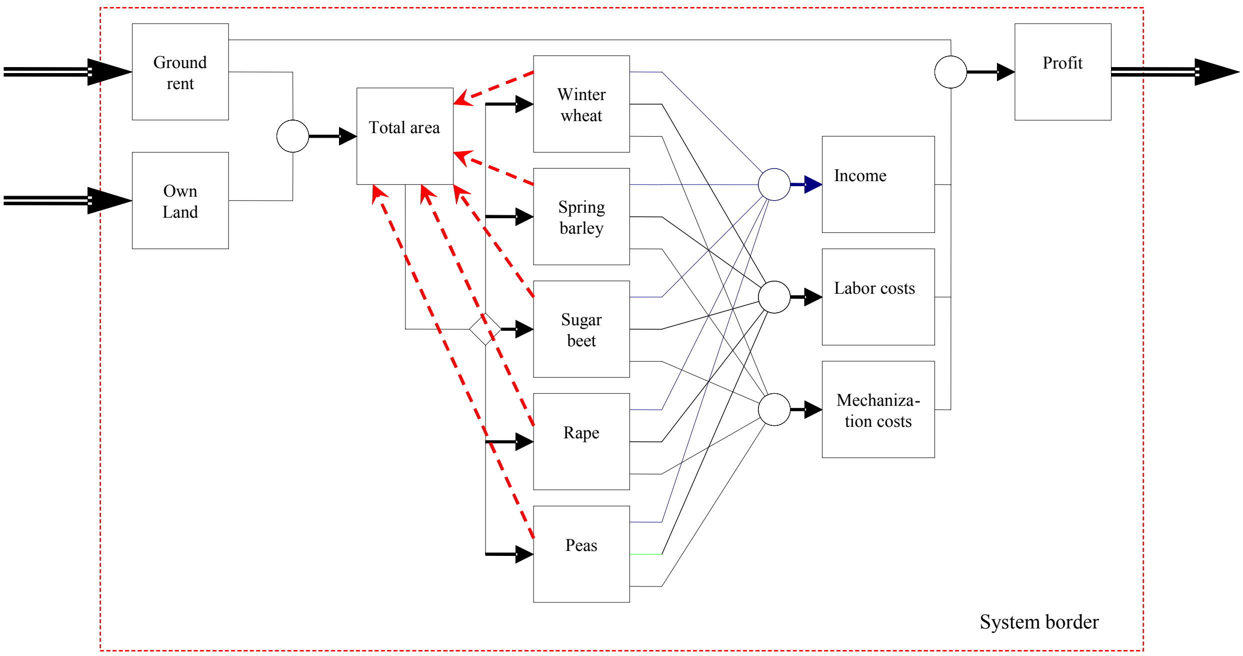

Figure 2. System definition using graphical symbols

Source: authors

reality from the modeller's perspective. Therefore, it is an objectification of the reality, which in turn means a subjective view of the reality. Such a model can often be mathematical. Mathematical models employ mathematical tools, symbols and notations, including numbers

Defining variables, setting up coefficients

Each system element will be represented by one variable (x_j) and each objective function cost coefficient will be set. Because economic consistency and all economic dependencies and links are expressed using internal relations only (in the form of balance constraints), the only objective to be maximized is profit. Thus all variables cost coefficients are equal to zero, only the profit coefficient is equal to one.

Example: In this phase, the coefficients of revenues (incomes) and costs of all crops are added to the relationships. The coefficients expressing costs (land rent, labour costs, and mechanization costs) are negative due to the further comparison with incomes in the profit calculation formulas. Further, the ratios and balance coefficients are set (Figure 3).

Model completion – building of a knowledge map

Completion of constraints and the objective function is the last step of the model construction.

Example: This model consists of 2 capacity constraints, 6 balance constraints and 5 ratio constraints. Constraints of the economic type are formulated as equations (Figure 4).

In this phase, the issuing model diagram can be read as a knowledge map. Crossing the system border from the left (two double arrows) allows us to follow the process of building constraints on the basis of the agro-technology requirements and restrictions. When leaving the system border on the right, the mathematical model is created and a new knowledge map how to do this is born.

Model testing and verification measure the quality of the model. The understanding created by the model and the effectiveness of the results of the application of any operations research models is a function of the degree to which the model represents the studied system. To define those conditions, which will lead to a valid and rational solution of the systems problem, the analyst must first identify a criterion by which the performance of the system may be measured. This criterion is often referred to as the measure of the system performance or the measure of effectiveness. If the model was built well, the model would adequately show the behaviour and problems of the investigated reality.

Model experiments follow the steps of the model building and model verification. The solution of the model with different data quantification provides different alternatives of the problem solving and can

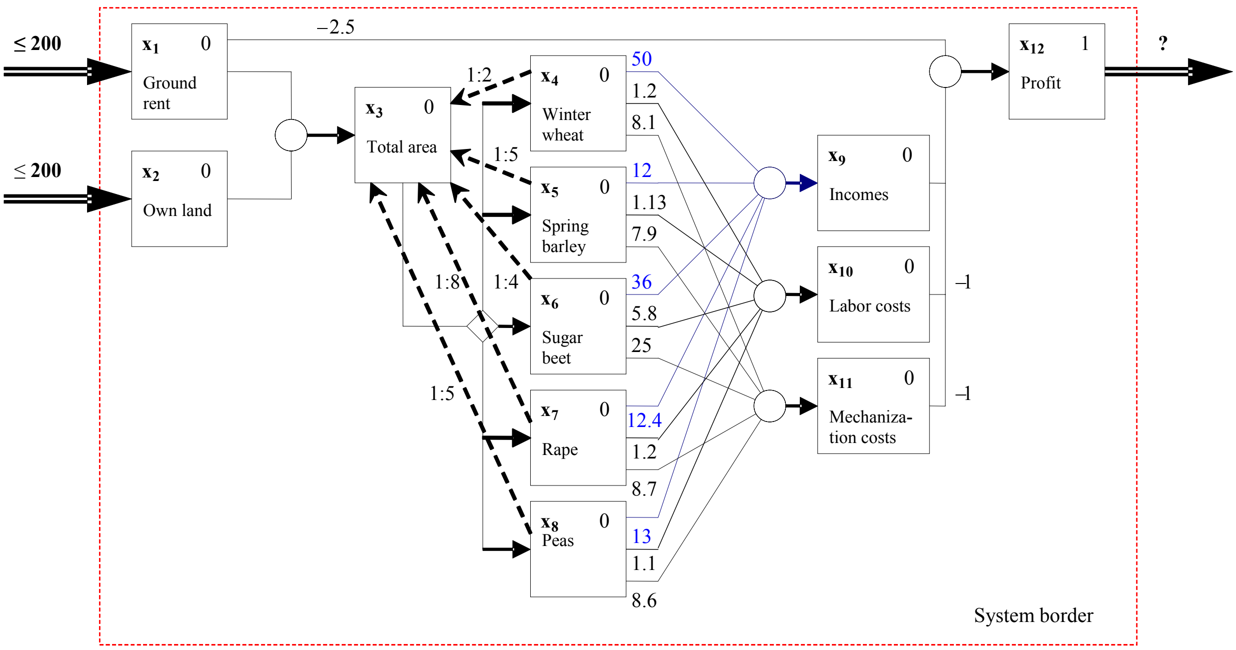

Figure 3. Variables definition, assignment of the model constraints and cost coefficients – quantification of relationships

Source: authors

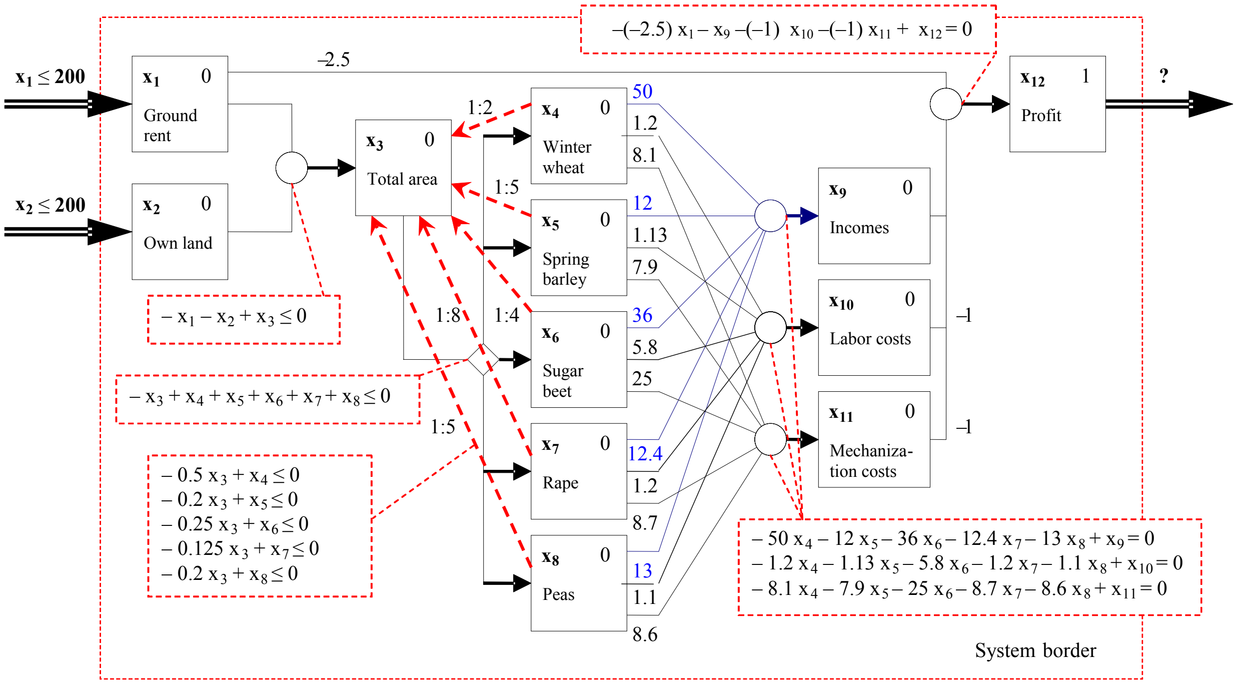

Figure 4. Model construction

Source: authors

improve the understanding of problems. Different algorithms (a series of steps that will accomplish a certain task) are used to realize these experiments. The study, understanding, and invention of such algorithms are also important parts of the OR/MS modelling.

Results interpretation and implementation – Completion and understanding the knowledge map: If the mathematical model is a valid representation of the performance of the system, by application of the appropriate analytical techniques the solution obtained from the model experiments should also be the solution to the system problem. The analytical results obtained from the analytic model must always be tempered with an experienced judgment, since some factors usually exist that could have not been included in the model. The communicative and political skills of the decision-maker are also needed

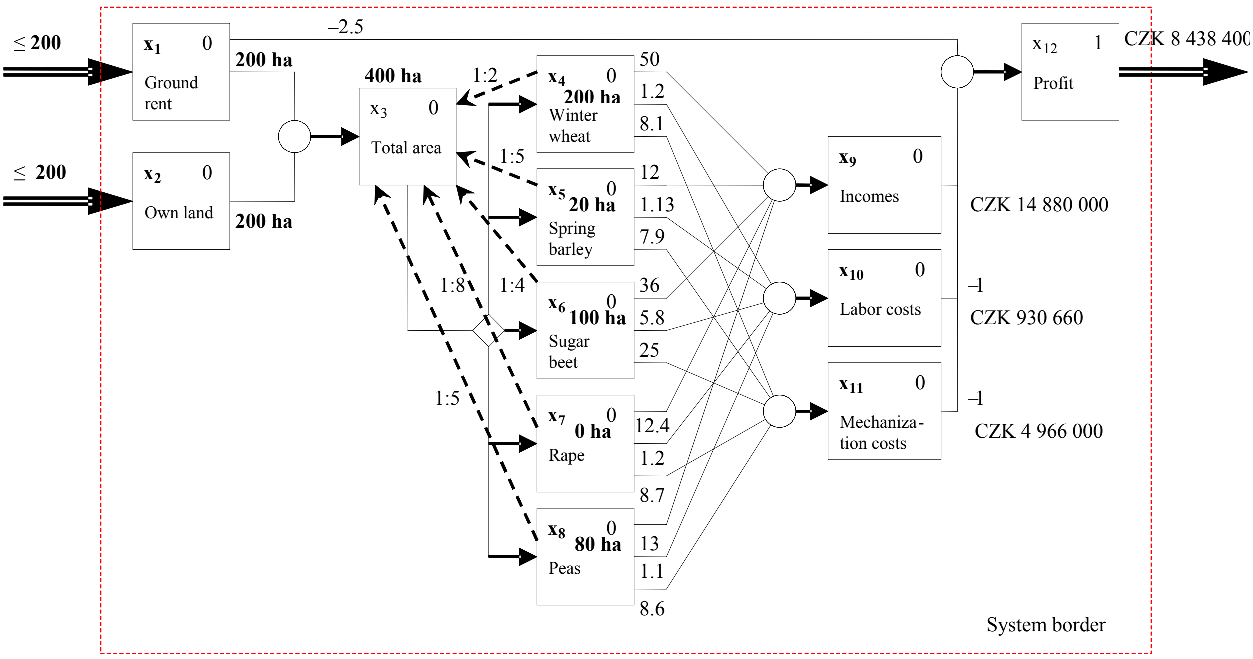

Figure 5. Model solution

Source: authors

in implementing the results of the OR/MS model in the real-life situation.

The knowledge itself consists in the ability of solving the real problem, primarily modelled. The knowledge map guides us through this solving process, through the process of the arising knowledge via the combination of graphical and semantic tools.

Example: Figure 5 represents the optimal solution of the farm production optimization model. The completed drawing of the model construction process containing also the optimization results is a chart having all necessary properties to be called a knowledge map.

CONCLUSION

The practical example from agriculture proves the possibility of using mathematical model as a knowledge map. In the decision-making process, knowledge is based on the experience with a successfully solved problem and with a solution of model respectively. A really popular way to formalize knowledge and to offer the way for finding it is a knowledge map. Model, especially mathematical one, can be a general tool for knowledge searching, formalization and keeping.

On the relevant application of the model – knowledge map creation process with agricultural topics, we demonstrated that:

- Problem definition is achieved using a general mind map. Such a mind map is a descriptive knowledge map.
- System definition can be made using a general concept map, which is a descriptive map too.
- Mathematical model is formulated using a descriptive or normative map. (It depends on the model type).
- Problem implementation describes a prescriptive map.
- Management science model creation consists of analogous steps as a knowledge map creation, where relationships between the corresponding elements are as follows:
  - Variables are related to topics, ideas or concepts,
  - Constraints and transformation are related to branches and finally
  - Model evaluation is related to map evaluation.

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